

## ***Interactive comment on “Retrieval of ozone profiles from GOMOS limb scattered measurements” by S. Tukiainen et al.***

### **Anonymous Referee #3**

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### **General comments:**

The paper presents interesting results on the ozone profile retrieval from measurements of scattered sunlight from the GOMOS instrument. Although not stated explicitly this seems to be the first publication on this topic. With no doubt the obtained results complement the stellar occultation dataset from GOMOS and are important for atmospheric studies. The presented comparison results are promising and I would like to encourage authors to perform an extensive validation in a follow-up study. Unfortunately the paper is written not carefully enough and some important contents are missing. The retrieval algorithm is insufficiently discussed and the description of the stray light correction method is unclear. It is also unclear if the results of very limited

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comparison with OSIRIS are also valid for other atmospheric or observation conditions. The abstract is wrongly focused and provide improper conclusion on the retrieval accuracy. No concise formulation of the conclusions is given. Nevertheless, my impression is that after a moderate revision according to my specific comments below the paper might be considered for publishing in AMT.

### Specific comments:

1. Abstract: The first two sentences of the abstract are not in line with the focus of the manuscript as they give an impression that GOMOS uses only the stellar occultation technique.
2. Abstract, line 14: “better than 10% at 22–50 km” - This estimation is true only for the comparison between GOMOS night OCC and GOMOS GBL. For the comparison between GOMOS and OSIRIS a statement “better than 20%” would be more appropriate. The abstract must not present only the best case conclusions.
3. Introduction, lines 22-24: “Limb-viewing instruments can directly observe solar or stellar signal as it is occulted by the atmosphere, but limb scattered indirect sunlight, or radiance, can be used as well.” - From this sentence one gets an impression that the scattered light measurement technique is something really new in comparison to well-established occultation geometry. This would have been true if it had been stated shortly after the launch of Odin and ENVISAT satellites 8-9 years ago. At present, the limb scattered light observation technique is widely approved and should not be introduced as a minor addition to occultation mode.
4. Introduction, page 4356, lines 24-25: “Compared to the nadir looking instruments, the limb-viewing technique can not achieve as good global coverage, but it yields superior vertical resolution.” - In principle, limb viewing technique can achieve the same global coverage as the nadir looking instruments. Most probably you mean horizontal resolution here.

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5. Introduction, page 4356, lines 25-26: “A major advantage of the stellar occultation technique is the possibility of night-time observations which is essential for, e.g., polar night studies.” - The topic of your paper is actually limb observation mode. What is a goal of discussing advantages of the stellar occultation technique?

6. Introduction, page 4357, lines 2-3: I think this sentence would benefit from more recent references.

7. Introduction, page 4356, lines 25-26: “The key element of the middle atmosphere is ozone, but there are several other observable species such as NO<sub>x</sub> and HO<sub>x</sub> compounds, BrO, OClO, aerosols and even metals. It is typically the wavelength band of the instrument that restricts which species are possible to detect.” - This two sentences have a relation neither to previous nor to subsequent text.

8. Introduction, page 4357, lines 11: I think a proper illustration of recent studies on ozone requires more references.

9. Introduction, page 4357: “The GOMOS (Global Ozone Monitoring by Occultation of Stars) instrument on board the Envisat satellite uses stellar occultation method to probe the atmosphere between 10 and 120 km.”: - Alone from the title of your manuscript one suggests that GOMOS can also measure the scattered sun-light. This sentence seems to claim that it is not the case.

10. Sect. 2: A subsection containing a short general description of GOMOS measurements needs to be provided. It should contain such information as how the scanning is performed, vertical and horizontal resolution, vertical sampling, spectral resolution and sampling and so on.

11. Sect. 2.1: Please explain what exactly is referred as the CCD saturation. From the electronic point of view one would expect that the saturation means that the CCD reaches the maximum of its dynamic range. In this case however one might want to avoid the parts of the spectrum where the signal is high. As it follows from Fig 1, you

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reject rather the spectral parts where the signal is lower. Is there just a part of CCD which has an anomalously reduced dynamic range?

12. Sect. 2.2, Eq. 1: Index “-1” is ambiguous. It is better to write a fraction instead.

13. Sect. 2.2, line 10: “where  $I(\lambda, j)$  are measured radiances and  $\hat{I}(\lambda, j)$  are the radiances at 500 nm.” - the formulation gives an impression that  $\hat{I}(\lambda, j)$  are not the measured radiances. What are these? If this is a measured radiance you are weighting different tangent heights with a single point when averaging intensities. This puts a high weight to the noise at 500 nm. Is the averaging with noise-determined weights meaningful?

14. Sect. 2.2, line 11: “altitude index” → “tangent height index”

15. Sect. 2.2, line 11: “goes through the measurements above 100 km” - how many measurements and at which tangent heights are these?

16. Sect. 2.2, lines 13 - 16: You write you fit the radiance with a polynomial at each wavelength. In this case you can easily extrapolate the radiance to the low altitudes but it is unclear how you are doing this with the stray light. Do you use the polynomials from the radiance fit to re-calculate the stray light? If yes you have to associate your stray light to any tangent height. Which one is that? If it is not the case please explain how you do the extrapolation.

17. Sect. 2.2, lines 13 - 16: Suppose you have somehow extrapolated your stray light to the low altitudes. How do you proceed to get back to the radiance from the dimensionless ratio, i.e., to obtain the red circle in Fig. 2?

18. Sect. 2.2, lines 13 - 16: Why is not the stray light as given by Eq. (1) calculated starting from the same tangent height  $\hat{z}$  as used later for the fit? What is a goal to fix the lowest altitude for the stray light at 100 km and use a dynamic value for the fit range?

19. Sect. 2.2, lines 24 - 25: “In reality, the amount of stray light may actually vary as a

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function of altitude leading to abnormal results from the extrapolation.“ - How are these abnormal results identified and how are they treated then?

20. Sect. 2.2, page 4359 line 25 and page 4360 line 1: “Stray light is dependent on the albedo below the satellite” - I think you mean “below the tangent point”. The satellite is quite far away from the probed area and, thus, I do not think that albedo below the satellite makes any effect.

21. Sect. 2.2, Fig. 2: Please discuss physical/instrumental reasons why the stray light should decrease below 50 km.

22. Sect. 3: OSIRIS is known to measure typically at large solar zenith angles. For this conditions one can expect the highest contamination due to the direct sunlight penetrating into the instrument but the lowest contamination due to the scattered light. As you highlight the influence of the surface albedo I guess the latter contribution is at least comparable to the first one. It is extremely important to investigate which source dominates. This is the only way to draw a conclusion if the considered coincidences represent best or worst case with respect to the stray light contamination of GOMOS measurements.

23. Sect. 3.1: “This is because the slit of GOMOS is much larger than of OSIRIS.“ - The fact that a poor spectral resolution of a spectrometer is usually determined by a large entrance slit is broadly known. Thus, the sentence is unnecessary.

24. Sect. 3.1: “The best estimate of the slit function is shown in Fig. 3.” - How has this estimation been obtained?

23. Sect. 3.1: “weak spectral resolution” → “low spectral resolution”

25. Sect. 3.1: The following statements are in a contradiction: “... whose absorption fingerprint is small.” and “... using the strong NO<sub>2</sub> absorption features in the 430–450 nm region.”

26. Sect. 3.1: What is a reason for discussing NO<sub>2</sub> in a paper dealing with ozone

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retrieval?

27. Sect. 3.2, line 10: “vertical sampling resolution” - vertical sampling and vertical resolution are different characteristics. Which one do you mean here?

28. Sect. 3.2, Fig. 5: Further in the course of the manuscript you are focusing on the 30 km tangent height. It would be interesting to see the plot similar to Fig. 5 for this tangent height as well.

29. Sect. 3.2 - 3.3, Figs. 5 - 8: I am wondering why the upper tangent height in the plots and/or ratios is always different. First you plot 50 km then go for 47 km when averaging and finally plot 55 km. I think it would be more consistent if you use always the same tangent height.

30. Sect. 4., lines 12 - 13 : “For every measurement layer  $j$  ...” - You do not measure any layers. May be you mean “tangent height”?

31. Sect. 4, Eq. (2): Does  $\hat{I}_{ref}(\lambda)$  in the denominator include multiple scattering?

32. Sect. 4, Eq. (2): It is unclear how to make a least squares fit as there is no fitting parameter in the equation.

33. Sect. 4: Table 2 should be referenced already here. The solar zenith angle grid is suboptimal. The step size is unnecessary small for small solar zenith angles and too coarse close to 90 deg.

34. Sect. 4: Provide the formula for the trace gas density fitting procedure.

35. Sect. 4: “... using tens (or hundreds) of wavelengths in the 280–680 nm band” - From this sentence reader might get an impression you do not know how many wavelengths you have in your fit. Please be more specific.

36. Sect. 4: “... in the 280–680 nm band” - As you have shown in Sect. 3 the spectral signal below 350 nm is strongly contaminated by the stray light and the correction algorithm fails to provide reasonable results. What is the reason to include these wave-

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lengths in the retrieval?

37. Page 4363: Section “Radiative transfer model” has no number.

38. Page 4363, last line and Page 4364, first line: “More multiple scattering means slower execution. Smaller contributions come from the solar angles, atmospheric composition and albedo.” - The statements are misleading because the multiple scattering contribution is determined by the solar angle, atmospheric composition and albedo.

39. Sect. 5: “Below 22 km the standard deviation of the GBL profiles increase significantly.” - The standard deviation of GBL profiles is not shown.

40. Sect. 5: “It is difficult to follow occultating stars at low tangent altitudes, and especially when clouds enter the line of sight.” - It should actually affect both GBL and night OCC measurements in a similar manner. Thus, it can not be an explanation for the differences in Fig. 10. Or may be you want to say something else with this sentence. Please clarify.

41. Sect. 6: “The spectral resolution of GOMOS (bright limb signal) is poor, about 3 nm compared to the  $\sim 1$  nm resolution of OSIRIS.” - this is actually not an issue for ozone retrieval which is the topic of the paper.

42. Sect. 6: “Unfortunately, close matches between OSIRIS and GOMOS measurement times, tangent point locations, and solar angles are rare and only 13 cases were investigated in this paper.” - This might be an indication that OSIRIS was not the best choice for your comparisons.

43. Sect. 6: The word “validation” is not applicable to the presented set of comparisons because it is quite sparse and limited to certain latitudes. The word “verification” would be much more appropriate.

44. Sect. 6: “Finally, it should be noted that the validation for profiles shown in this paper are preliminary ....” - Noun and verb are inconsistent : “... validation ... are ...”

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45. Sect. 6: "... and should be repeated using other reference instruments for all latitudes." - "repeat" means do exactly the same. I think you want to "extend" rather than "repeat" the comparisons.

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Interactive comment on Atmos. Meas. Tech. Discuss., 3, 4355, 2010.

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